Renewable and Sustainable Energy Reviews 16 (2012) 2111–2117

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Exploitation and utilization of the wind power and its perspective in China

Yu Ling [a,b,*], Xu Cai [a,c]

[a] WPRC, School of Electronic Information and Electrical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
[b] Department of Electrical Engineering, Shanxi Datong University, Datong, Shanxi 037003, China
[c] SKLOE, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

ARTICLE INFO

Article history:
Received 15 April 2011
Received in revised form 8 January 2012
Accepted 10 January 2012
Available online 18 February 2012

Keywords:
China
Development
Renewable
Wind
Wind energy

ABSTRACT

Wind energy, as a reliable, natural and renewable electrical power supply, produces no emissions and so it is an excellent alternative to conventional, more heavily polluting fuels in the long term based on the worldwide concern about the environment and energy supply. Wind energy resources in China are affluent, but its distribution are uneven, centralized, and far from both the utility and the high electricity demand markets. This made China's onshore wind power development have such characteristics as large scale, high centralization and far transmission, which is different with that in Europe, where the characteristics are even distribution, decentralized. In past two decades, considering the economic, technical and environmental benefits of wind power, China has given priority to its development. Besides the dramatic growth of large scale grid-connected wind power, household-scale wind power has been used most successfully in remote rural regions in China. Therefore, the development of wind power will be of great importance to alleviate the energy crisis and environmental pollution resulting from the rapid economic growth of China in the future. In this paper, the current development of wind energy utilization in China is investigated, and some critical barriers are discussed. Finally, the perspective of wind energy utilization is presented, where focuses are placed on seven wind power bases.

Contents

1. Introduction 2111
2. Wind resources in China 2112
   2.1. Onshore wind resources in China 2112
   2.2. Offshore wind resources in China 2112
3. Current development of wind power generation in China 2113
   3.1. Overall status 2113
   3.2. Wind power development in Inner Mongolia 2114
   3.3. Offshore wind power development 2114
4. Challenges in utilizing wind energy in China 2115
5. Future prospect 2115
6. Conclusion 2116
   References 2116

1. Introduction

Energy resources are the supporting industry of a nation's economy and society development. With the fast increasing of China's economy over the last three decades, China is also becoming an energy consumption big power, and its total primary energy consumption had been up to 3249.39 million tons of standard coal as calorific value calculation in 2010. However, it is worth noting that the consumption of coal and petroleum, and nature gas constituted 68%, 19% and 4.4% of the total annual primary energy consumption, respectively [1]. It is difficult to change this situation any time soon. As a result, China is facing many challenges from the extensive use of fossil energy resources. For example, it is worldwide recognized that fossil energy resources will not last very much longer, and their exploitation and utilization seriously pollutes the environment and

* Corresponding author at: No. 800, Dongchuan Road, Mulan Biulding B111, Shanghai 200240, China. Tel.: +86 21 34207001x607.
E-mail address: pleasurely@126.com (Y. Ling).

1364-0321/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2012.01.039

discharges a large quantity of greenhouse gases. So it is seriously threatening the capacity for China's sustainable development.

In practice, most of the present energy demand is used in generating electricity. By 2010, the total installed capacity of electric power had reached 966 GW, which represents a 10.56% growth rate in this year in comparison with the year of 2009. However, In spite of the fast increasing of electricity generation, the electricity supply cannot yet meet the demand well, which had contributed to cuts in power supply in many areas, especially in peak-value time, as the total electricity demand in China in 2010 was 4199.9 TWh [2], and is projected to reach 5990–6570 TWh in 2015 [3]. As a result, coal use is expected to increase greatly in order to electrical power needs in the next couple of decades. This will result in a significant contribution to world CO_2 emissions. As a matter of fact, Chinese emissions were more than six billion tons of CO_2 in the year 2009, accounting for about 22% of global emissions [4].

In order to deal with energy crisis and global climate warming, as all other countries around the world, efforts have been made to generate electricity from renewable electrical energy in China. One way of generating electricity from renewable energy resources is to use wind turbines, which can convert the kinetic energy contained in the wind into electrical power by using modern wind energy conversion technologies. Due to their advantages, together with institutional and governmental support on wind energy and improvement of modern wind energy conversion technology, by the end of 2009, China's market for the electrical power produced by the wind turbine generator (WTG) has been up to 27.615 TWh, demonstrating a 111.14% year-on-year increase [5], and in the year 2010, with a 78.89% increase in comparison with the year of 2009 [2]. Compared with fossil fuels, wind turbine generators (WTG) have a number of advantageous characteristics that are presented as following [6,7]:

- Wind energy is essentially a natural, infinite and renewable electrical power supply, that is, it will never be depleted during the generation of the electricity, which can be realized through modern wind turbines technologies.
- The generation of the electricity from wind energy is environmentally friendly. It does not emit CO_2 and create any toxic by-products.
- As a matter of fact, all forms of energy production have an effect on the environment, but the impacts of wind energy are low, local, and manageable. These environmental impacts are negligible when compared with conventional fossil energy sources.
- Wind energy can do more than the production of the electricity such as water pumping, grinding grain, sawing wood and power tools.

At present, there are different alternatives for wind power generation utilization such as so-called "on-grid" and "off-grid". On-grid wind power means that wind power generation system is connected to the power grid, and the electricity that is produced by wind turbines is transmitted to power consumer through the grid, while its counterpart, off-grid means that wind power generation systems are isolated, and without connection to the grid. In general, energy storage components are need to ensure the electricity supply during the periods of low or no power output, this can be because that wind power outputs can fluctuate on an hourly or daily basis. Alternatively, the wind can also be used in a hybrid concept with diesel engine generator, with fuel cells or photovoltaic power system.

The main objective of this paper is to give a quick overview of the distribution of wind energy resources, and to investigate the current development of wind energy utilization in China. In turn, some critical barriers are discussed. Finally, the perspective of wind

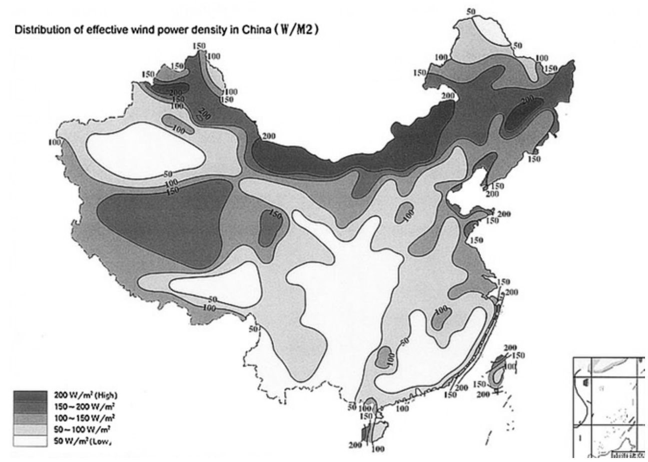


Fig. 1. Wind energy resources in China.

energy utilization is presented, where focuses are placed on seven wind power bases.

2. Wind resources in China

2.1. Onshore wind resources in China

China is endowed with large wind energy resources, especially in the north and the southeast along the coastline. As the third general survey of national wind resource of China meteorological Administration, the theoretical exploitable storage of wind energy in China has been estimated at 4350 GW, and the technological available storage is in the order of 297 GW at a 10 m height [8]. In fact, modern turbine hub height has been up to 50 m, at which the technological available storage could be two times this figure. This is because wind speeds typically increase with height above the ground [9]. The distribution of effective wind power density is shown in Fig. 1 [10]. As shown in Fig. 1, based on the criterion of division presented in Table 1 [9], in which the parameters are averaged over the region, there are several main regions, where wind energy resources are richer than that of other regions.

In the three north regions including Northeast China, North China and Northwest China, wind power density can reach 200–300 W/m^2, and even reaches 500 W/m^2 in a few specific sites, which can be hundred of square kilometers. The time duration above wind speed of 3 m/s is higher than 5000 h, and even 7000 h above in a few sites [8].

Coastal wind resources along the southeast coast in China are also rich, with a wind power density of 200 W/m^2 above. The time duration above wind speed of 3 m/s varies between 7000 and 8000 h such as in Taishan, Pingtan and so on [8]. However, due to the lack of coal resources, together with local rapidly increasing of electricity demand and high electricity prices make wind energy utilization have very good prospects. But the lack of land resources can limit the development of coastal wind power.

2.2. Offshore wind resources in China

The Offshore area has been divided into different classes depending on the distance from the coastline, specifically area less than 10 km from the coast, areas 10–30 km away, areas 30–60 km away and areas more than 60 km away [11]. Offshore wind farms are constructed in general on the continental shelf in sea area which is about 10 km away from the coast, with less than the depth of 30 m [12].

Table 1
The criterion of division on wind energy resources.

Wind potential region	High	Moderate	Marginal	Poor
Annual available wind energy density (W/m^2)	>200	200–150	150–50	<50
Time duration above wind speed of 3 m/s (h/year)	>5000	5000–4000	4000–2000	<2000
Time duration above wind speed of 3 m/s (h/year)	>2200	2200–1500	1500–350	<350

However, along the path from shallow water through transitional water to deep water, wind energy resources become increasingly rich. This reason can be that offshore wind energy resources depend largely on the distance from the coast. As estimated, the total available offshore wind energy storage of China may reach approximately 100 GW at the offshore depths of 10 m, approximately 300 GW at the depth of 20 m, and approximately 490 GW at the depth of 30 m, respectively. The total available wind energy of offshore area of China is 3 times that of onshore area of China [9]. So offshore wind power has very good perspective.

3. Current development of wind power generation in China

3.1. Overall status

Wind power is the fastest-growing energy resource both in China and worldwide in the recent years, which can be seen in Fig. 2 [2,5,13,14], which presents the annual growth rate of electrical power installed capacity by primary energy resource. From the figure, between the years 2006 and 2010, the growth rate of wind power installed capacity was a great deal higher than any other electricity generating technology in China. Fig. 3 shows the share of wind power in the total installed capacity of electrical power. Though wind power increased its share in total electrical power installed capacity from only 0.2% to 0.6% in the year 2007, up to 2.01% in 2009, and further up to 3.06% in 2010, it is still the weakest sector among electricity generating technologies. In 2010, the electricity production from wind power is 49,400 GWh, with an increasing of 21,785 GWh in comparison of that of 2009 [2]. The share of wind power in electrical power production is presented in Fig. 4. There is a slight increasing trend over this period. In 2010, wind power contributed 1.17% of total electricity production, which is about 12.3 times that of 2006, which can be seen in Fig. 4. Note that the data in Figs. 3 and 4 are calculated in terms of the electricity industry statistics made by the China Electricity Council [2,5,13–15].

In fact, China's efforts to develop wind power generation can be traced back to the early 1970s. Since then, especially in the past two decades, wind power generation is increasing dramatically. A number of nation-level wind power projects have been completed to increase the contribution of the production and consumption of wind electricity. As a result, the total installed wind power capacity in China has increased from 341.6 MW in 2000 to 44,733.29 MW at the end of 2010 [16], with an average annual growth rate of 62.82%. Development of wind power in China between the years 2000 and 2010 is shown in Fig. 5 [16], which derived from the Chinese Wind Energy Association. From the figure, it can be seen here that, especially between the year of 2007 and 2009, wind power generation has grown dramatically at an average annual growth ratio of about 116%.

Due to the uneven distribution of wind energy resources, most of different scales wind farms have been established on Xinjiang Autonomous Region through Qinghai Province, Gansu Province to Inner Mongolia (IM), and the South-East Coastal Region of China and so on. The cumulative installed wind power capacity and its share in national installed capacity and the annual installed wind power capacity and its share in national installed capacity in leading provinces in 2010 is given in Table 2 [16]. It can be seen here that Inner Mongolia is the national leader in the wind energy sector, with wind power of 13,858.01 MW. Approximately 30.98% of the

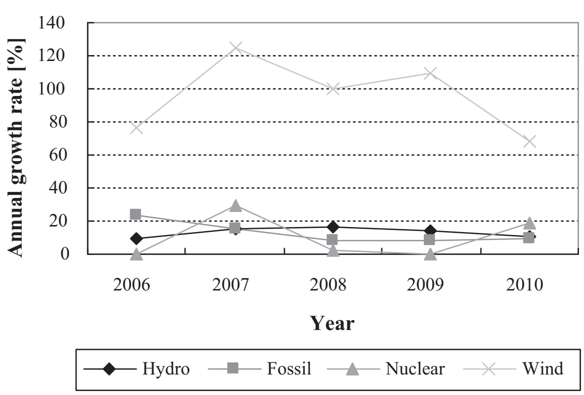


Fig. 2. Annual growth rate of electrical power installed capacity by primary energy resource.

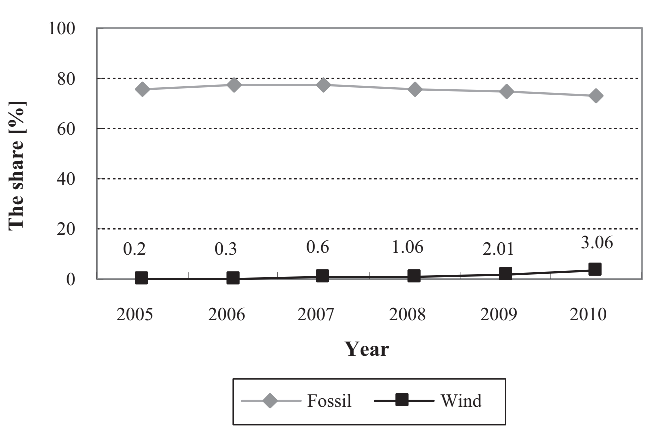


Fig. 3. The share of wind power and fossil power in the total installed capacity of electric power.

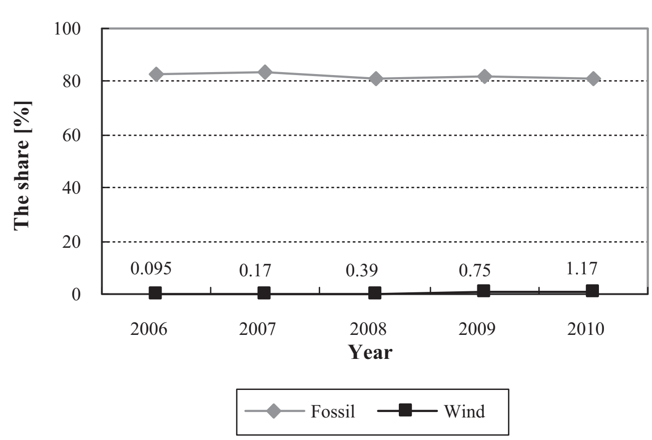


Fig. 4. The share of wind power and fossil power in the total productions of the electricity.

Table 2
Current status of wind power installed capacity in leading provinces in 2010 (MW).

	Inner Mongolia	Gansu	Hebei	Liaoning	Jilin	Shandong	Heilongjiang	Jiangsu	Xinjiang	Nation
Annual	4661.85	3756.0	2133.4	1641.55	877.00	1418.7	710.30	371.00	361.00	18,927.99
Annual share (%)	24.63	19.84	11.27	8.67	4.63	7.50	3.75	1.96	1.91	100
Cumulative	13,858.01	4943.95	4921.5	4066.86	2940.86	2637.8	2370.05	1467.75	1363.56	44,733.29
Cumulative share (%)	30.98	11.05	11.00	9.09	6.57	5.90	5.30	3.28	3.05	100

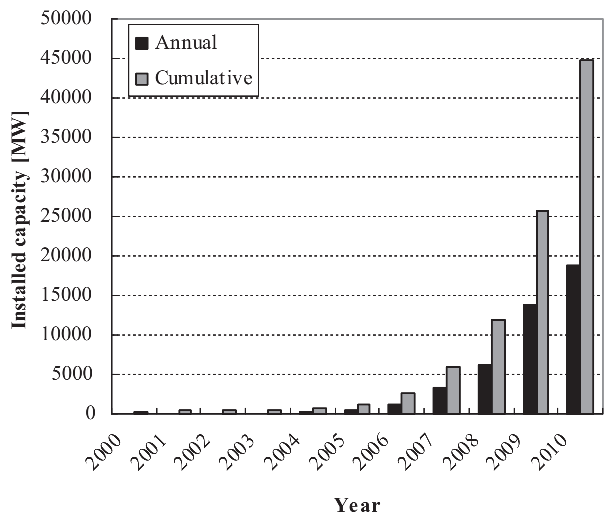


Fig. 5. Development of wind power in China between the years 2000 and 2010.

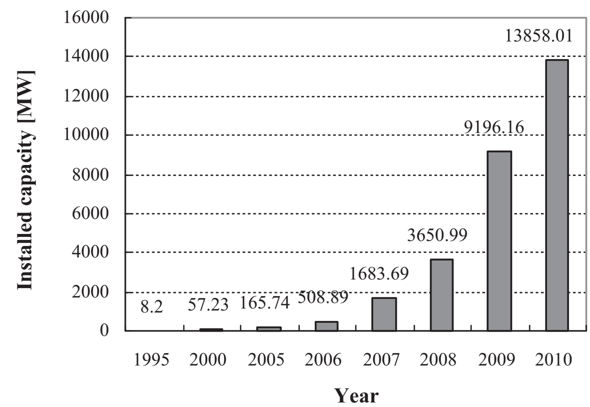


Fig. 6. Development of wind power in Inner Mongolia.

national total installed wind power capacity is in Inner Mongolia, 11.05% in Gansu and 11.00% in Hebei.

3.2. *Wind power development in Inner Mongolia*

Due to its special geographic characteristics such as relative high altitude, open terrain, low vegetation, few buildings, speed increasing effect when north-south air flows through the raised landform, and small ground friction [17], Inner Mongolia is abundant in wind energy resources. Furthermore, wind energy resources of Inner Mongolia have many advantageous characteristic such as wide distribution, high stability, and good continuity. Annually average wind speed is 3.7 m/s, and effective wind power density is up to 100–300 W/m^2 in Inner Mongolia at the height of 10 m [18,19]. In one word, Inner Mongolia is a perfect place for developing wind energy.

Inner Mongolia's efforts to develop wind power generation can be traced back to the 1970s. Due to abundant wind energy resources, together with prior consideration to develop wind power by both national and local governments, wind power utilization in Inner Mongolia is in the leading position among other provinces of China. At that time, in Inner Mongolia, there are about 6 millions people who live in remote rural areas, and so they have no access to conventional electricity services. In order to provide electricity access to remote herdsmen, household-scale wind power has been used most successfully in this region [17], and as a result this makes it possible to use wind power generators to charge batteries to power televisions, radios and lights for remote herdsmen. It is estimated that over 90% of the small-scale turbines in China are located in Inner Mongolia.

In 1989, the first onshore wind power generation farm was built, having a rated power of 500 kW and consisted of five 100 kW wind turbines produced by the American company in Zhurihe wind farm, in the north-central part of Inner Mongolia. From then on, Grid-connected wind power is well developed in Inner Mongolia. Subsequently, four other wind farms were constructed in succession: Shangdu in 1994, Xilinhot in 1995, Huitengxile in 1996, and Dali in 1999, with the total installed capacity of 135.14 MW at the end of 2004. Development of grid-connected wind power in Inner Mongolia increases dramatically, which can be seen in Fig. 6 [16,17]. The figure shows the Installed wind power capacity in Inner Mongolia between the years 1995 and 2010. In 1995, there was only 8.2 MW of wind power capacity installed in Inner Mongolia. However, 2009 is a record breaking year for wind industry in Inner Mongolia. At the end of the year 2009, the total installed wind power capacity has been up to 9196.16 MW, with 151.88% of growth rate in comparison with 2008. In the year of 2010, however, growth has slowed, and there is still a 50.69% increase rate in contrast with 2009.

3.3. *Offshore wind power development*

At present, the vast majority of wind power is generated from onshore wind farms. However, offshore wind power can be the trend in the near future, especially in Europe [11]. This is because that offshore wind farms have many advantages comparing with onshore. For example, wind speeds are higher and more stable on the open sea. Wind turbines can also be bigger than on land because it is easier to transport very large components on the open sea. As estimated, there is a huge increase in wind energy development over the following 20 years.

Onshore wind energy has grown enormously ever the last two decades in China. However, development of offshore wind power is just beginning. But there are substantial plans in the pipeline in several provinces, which can be seen in Table 3 [20]. From the table, it is found that several offshore wind farms with a total of thousands of megawatt will be constructed in Chinese sea in next two decades. As China' major urban centers, which are located on the eastern coast of China, are very far from these regions that are rich in wind

Table 3
Total offshore wind power installed capacity by province in 2015 and 2020 (MW).

Year	Shanghai	Jiangsu	Zhejiang	Shandong	Fujian
2015	700	4600	1500	3000	300
2020	1550	9450	3700	7000	1100

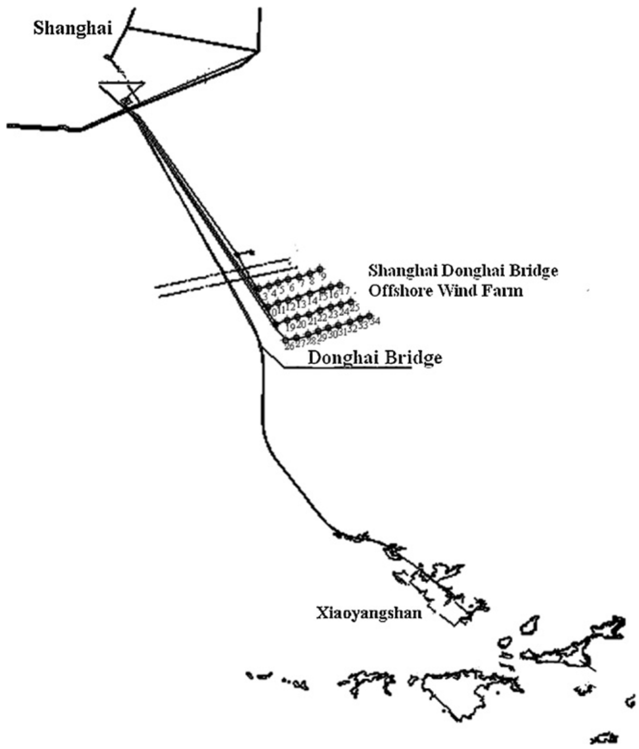


Fig. 7. The location of Shanghai Donghai Bridge Offshore wind farm.

energy. Though coastal wind energy resources are abundant, the growth of large scale onshore wind power is limited by the lack of inexpensive land resources in these regions. So offshore wind energy development, the same as other countries, has very good economic prospects in coastal region of China.

In fact, major urban centers such as Shanghai, are located on the eastern coast of China, in which electricity demand is growing rapidly and electricity prices are high, this is because local coal resources are scarce, coal must be transported in the region via rail or the electricity must be carried through long transmission lines. However, it is worth mentioning that offshore wind farm can be installed near major urban centers, only relatively short transmission lines to carry the electricity to these high energy cost and big demand markets.

At the end of the year 2010, the first offshore wind farm in China, Shanghai Donghai Bridge Offshore Wind Farm, has been built, having a total installed capacity of 102 MW and consisted of 34 wind turbines of 3 MW each produced by the Chinese company. The annual electrical power production will be equal to 258.51 GWh/year, which can meet the electricity demand of 200 thousands average households of Shanghai [20]. The location of wind farm can be seen in Fig. 7 [21].

4. Challenges in utilizing wind energy in China

China is a huge emerging market for wind energy which can be harnessed to provide enormous electrical power to both the remote rural areas which cannot access to a reliable electric network and these regions that are lack of conventional fossil fuel energy resources. Moreover, exploitation of wind energy will substantially benefit the coastal areas.

So far, although some efforts in China have been made, more research and development (R&D) on technology and policies related to wind energy is still urgently needed. (1) Distribution of wind energy resources is badly uneven in China, which can be disadvantageous to the development of wind energy. For a long time, the supply and demand of the electricity is unbalance in China. As mentioned above, China's wind energy resources are mainly distributed in three north of China, where the electricity demand is relatively small. So, due to the high transition cost, together with lack of the relevant technology, it is unfeasible to carry the electricity to coastal regions via long transition line. (2) At present, most of large scale wind farm were installed in the three north regions of China, and these wind farm are far from the local existing electrical power grid, which is weak. So this situation limits the capacity of the wind power integration into the utilities networks, and meanwhile, long transitions must be need to carry the electricity produced by wind farms to the local grids. In turn, new challenges occur such as the capacity of electricity transition, the transition cost, and the influence on topological structures, stability, and operating modes of power system [22]. (3) Large scale wind power make new technological demands on wind power industry not only with respect to the development of the wind turbines themselves but also with respect to their connection to the electricity grid. In order to capture more energy from the wind, novel blade should be developed and tested, and advanced control strategies such as maximum wind energy extraction should be investigated. At the same time, the low voltage ride through performance must be enhanced in order to meet the new grid codes that require the uninterrupted operation of wind power generation even through voltage dips caused by any fault [23]. (4) International co-operation will be of importance for the development of wind energy in China. It is hoped that more and more domestic and foreign institutions can share their experience on the wind energy exploitation. (5) Institutional and governmental support is needed to encourage more corporations to join the R&D of the wind energy.

Besides all mentioned above, there are still many other challenges needed to be solved for the development of wind energy such as the cost effectiveness, environmental impact analysis, so more researches and data from full-scale experiments are needed before any definite conclusions can be drawn.

5. Future prospect

In order to satisfy the rapidly growing energy demand, deal with the global challenges of climate change, and ensure the safety of energy supply, the National Medium and Long-Term Development Plan of Wind Power is issued by the National Development and Reform Commission of China in 2003, which puts forth the goal of the total installed capacity of wind power will reach 4 GW by the end of 2010, 10 GW up to 2015, respectively, and at the same time, offshore wind power projects on the southeast coast will be constructed. By 2020, the total installed capacity of wind power will be up to 20 GW in China [24].

In 2007, a more ambitious project than that enacted in 2003, in the Medium and Long-term Development Plan for National Renewable Energy Sources enacted in August, 2007, puts forward that the total installed capacity of wind power nationwide would reach 5 GW by 2010. Up to 2020, the national total installed capacity of wind power will come to 30 GW. In addition, offshore wind power will reach the installed capacity of 1 GW [25].

As a matter fact, China's total installed capacity of wind power at the end of 2009 has been up to 25.8053 GW, which has been significantly exceeding the planned wind power capacity of 2010, which is enacted both in 2003 and in 2007. As the plan enacted in 2003, offshore wind farms will be constructed in 2015, and however, in practice, at the end of 2010 Shanghai Donghai Bridge Offshore Wind Farm has been built. So it is found that national projects are conservative.

Besides all mentioned above, however, it is worth noting that on the base of previous construction, seven wind power bases, with a

Table 4
Total wind power installed capacity by wind power base in the future (GW).

Year	Jiangsu	Xinjiang	Gansu	Hebei	East IM	West IM	Jilin	Total
2015	5.8	7	n.a.	8.98	823.45	17.95	10.115	n.a.
2020	10	10.8	12.71	14.13	20	38.3	122.115	228.055

n.a.: data not available.

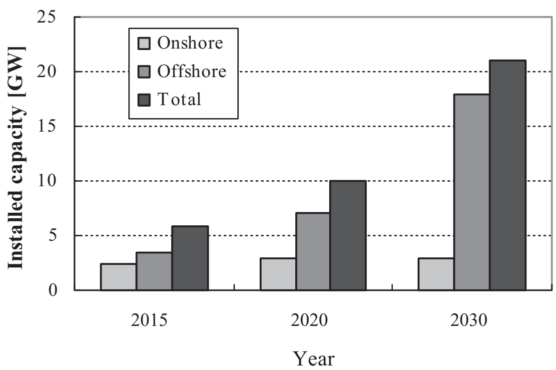


Fig. 8. Wind power installed capacity in Jiangsu wind power bases in the future.

wind power installed capacity of more than 10 GW each, have been projected in Gansu, Xinjiang, Hebei, Jilin, Inner Mongolia (IM), and Jiangsu, respectively, and this can imply a wind power development mode of large scale, high centralization and far transmission in the near future in China, which can depend on the distribution characteristic of China's wind energy resources. Table 4 presents the planed wind power capacity by wind power base. As seen from the table, at the end of 2020, Jilin will lead the sector with 122.115 GW. West IM will follow with 38.3 GW. East IM will be the third place, with 20 GW. In turn, Hebei, Gansu, Xinjiang, Jiangsu is, respectively, 14.13 GW, 12.71 GW, 10.8 GW, 10 GW, and these add up to 228.055 GW [20], which is more than 7 times the wind power installed capacity of 2020 planned in 2007.

Finally, it is worth mentioning that a 20-year program for the development of wind power in Jiangsu wind power base has been enacted by energy planners in local government. Fig. 8 shows the planed wind power installed capacity in next two decades. From the figure, offshore wind power installed capacity will increase significantly, and by 2030, it will reach 18 GW, constituting 85.71% of the total planned installed capacity in Jiangsu wind power base.

6. Conclusion

The current intent to reduce greenhouse gas emissions and conserve fossil fuels has resulted in a drive to clean and renewable energy, especially the large majority of aerodynamic energy contained in wind has gained more attentions recently and as a consequent wind power has developed considerably. It is well known that wind energy is a reliable, natural and renewable electrical power supply. Utilization of wind power can increase considerably the clean power supply, and reduce the emission of greenhouse gases, and meanwhile it is increasingly applied just to contribute to optimize energy structure and so enhance the capacity of economic and social sustainable development.

Wind energy resources in China are affluent, but taking into consideration the distribution characteristics of onshore wind energy resources, which are uneven, centralized, and far from both the existing utilities and the high electricity demand markets. This made China's onshore wind power development have such characteristics as large scale, high centralization and far transmission, which is different with that in Europe, where the characteristics are small scale, distribution, decentralized [22]. In past two decades, onshore wind power increase fast, but offshore wind power in China is only in beginning. Besides the utilization of large scale grid-connected wind power, household-scale wind power has been used most successfully in remote rural regions in China, and resultantly this has met local residents' electricity demand. With the great efforts and ambitious plans made by China, it can be foreseen that wind power in this country will increase dramatically. It will certainly play an important role in the economic development and global environmental protection. Of course, this depends on to large extent the support of both central government and local government on the exploitation of wind power. It is the concern on environment, energy that has driven the increasing interest in and application of wind power.

References

[1] National Bureau of Statistics of China. China energy consumption statistical data; 2010. http://www.stats.gov.cn/2011 [retrieved 03.01.12].
[2] The China Electricity Council. China electricity industry annual development review; 2010. http://tj.cec.org.cn/niandufazhanbaogao/2011-06-27/58873.html [retrieved 03.01.12].
[3] The China Electricity Council. China's future electricity industry. http://www.cec.org.cn/zhuanti/kaijuzhiniankandianli/zhongdianlianshierwuguihua/2011-02-23/44186.html; 2011 [retrieved 24.02.12].
[4] The International Energy Agency. CO_2 Emissions from Fuel Combustion Highlights, 2011 Edition. http://www.iea.org/ [retrieved 03.01.12].
[5] The China Electricity Council. China electricity industry annual statistics; 2009. http://www.cec.org.cn/d/file/tongjixinxibu/tongji/niandushuju/2010-11-17/e8490020d320055847e0558a0fc3e956.rar; 2010 [retrieved 02.11.12].
[6] Patel MR. Wind and solar power systems. New York: CRC Press; 1999.
[7] İlkiliç C. Wind energy and assessment of wind energy potential in Turkey. Renewable and Sustainable Energy Review 2012;16(2):1165–73.
[8] Xiao C. Europe and the USA wind power development experience and enlightenment to China. Beijing: China Electric Power Press; 2010.
[9] Lew DJ. Alternatives to coal and candles: wind power in China. Energy Policy 2000;28:271–86.
[10] Center for Wind and Solar Energy Resources Assessment, China Meteorological Administration. http://cwera.cma.gov.cn/cn/; 2010.
[11] Bilgili M, Yasar A, Simsek E. Offshore wind power development in Europe and its comparison with onshore counterpart. Renewable and Sustainable Energy Reviews 2011;15(2):905–15.
[12] Zhixin W, Chuanwen J, Qian A, Chengmin W. The key technology of offshore wind farm and its new development in China. Renewable and Sustainable Energy Review 2009;13:216–22.
[13] The China Electricity Council. China Electricity Industry Annual Statistics; 2006. http://www.drcnet.com.cn/2007 [retrieved 01.11.10].
[14] The China Electricity Council. China Electricity Industry Annual Statistics 2008. http://www.drcnet.com.cn/2009 [retrieved 01.11.10].
[15] The China Electricity Council. China Electricity Industry Annual Statistics; 2005. http://www.cec.org.cn/zhengcefagui/2010-11-27/11189.html [retrieved 01.11.10].
[16] The Chinese Wind Energy Association (CWEA). China's wind power installed capacity statistics; 2010. http://www.cwea.org.cn/download/display_info.asp?id=39 2011 [retrieved 01.11.10].
[17] Han J, Mol APJ, Lu Y, Zhang L. Onshore wind power development in China: challenges behind a successful story. Energy Policy 2009;37: 2941–51.
[18] Cen H-t, Zou W-w. The application of non-grid-connected wind power in high energy load industry in Inner Mongolia. Renewable Energy Resources 2010;28(5):147–9 [in Chinese].
[19] Li Q, Sheng Y, Bao T. Analysis of the advantages of wind energy resources in Inner Mongolia and exploitation. Northern Economy 2008;10:59–60 [in Chinese].
[20] Li J, Shi P, Gao H. China wind power outlook 2010. Haikou: Hainan Publishing House; 2010.
[21] Lu Z. Study on key technologies employed in planning and construction of Shanghai Donghai Bridge offshore wind farm. Engineering Sciences 2010;12(11):19–24 [in Chinese].

[22] Yi L-d, Zhu M-y, Wei L. Research on China's wind power development and grid-connection mode. Power System and Clean Energy 2008;24(3):35–9 [in Chinese].
[23] Morren J, de Haan SWH. Ridethrough of wind turbines with doubly-fed induction generator during a voltage dip. IEEE Transactions on Energy Conversion 2005;20(2):435–41.
[24] Fang C, Wang D. Predictive analysis and basic judgment of development targets in China's Wind Power Industry. In: World non-grid-connected wind power and energy conference. 2009. p. 1–4.
[25] The National Development and Reform Committee, the People's Republic of China. The Medium and Long-term Plan of Renewable Energy Source Development. Beijing, China; 2007.